Scymnus compunctus from the former, and the *Tenebrio Paivæ* from the latter. And when we likewise include an additional *Philhydrus* for S. Antonio, S. Vicente, S. Iago, and Brava, the exact numbers (as hitherto ascertained) for the respective *island*-catalogues will stand as follows:—

S. Antonio	115	S. Iago......	129
S. Vicente......	134	Fogo........	95
S. Nicolão......	27	Brava	62

XXVI.—*Notes on the Structure of the* Crinoidea, Cystidea, *and* Blastoidea. By E. BILLINGS, F.G.S., Palæontologist of the Geological Survey of Canada*.

1. *Position of the Mouth in relation to the Ambulacral System.*

The earlier palæontologists, Gyllenhal, Wahlenberg, Pander, Hisinger, and others, described the large lateral aperture in the Cystidea as the mouth, apparently on account of its resemblance to the five-jawed oral apparatus of the sea-urchins. In his famous monograph, 'Ueber Cystideen,' 1845, Leopold von Buch advocated the view that it was not the mouth, but an ovarian aperture, and that the smaller orifice usually situated in the apex, from which the ambulacral grooves radiate, was the true oral orifice. These opinions were adopted by Prof. E. Forbes in his memoir on the British Cystidea, by Prof. J. Hall in the 'Palæontology of New York,' and by most others who have described these fossils, including myself, in my first paper on the Cystidea of Canada, published in the 'Canadian Journal' in 1854. In 1858 I re-investigated the subject while preparing my Decade No. 3, and came to the conclusions that the lateral aperture was the mouth in those species which were provided with a separate anus, and that in all others it was both mouth and anus. The small apical orifice I described as an ambula-

* From Silliman's American Journal of Science, July 1869.

"This paper was prepared for the press last December; but as my collection of the Blastoidea was small, I thought it best to delay publication until I could examine a greater number of specimens. In January I applied to S. S. Lyon, Esq., of Jeffersonville, Indiana, and he replied that, if I would let him know what points I wished to investigate, he would supply me with the materials. On my giving him the desired information, he, in the most liberal manner, sent me a large collection (much larger than I expected to receive), consisting of numerous specimens of several genera, many of them in the state of preservation best adapted for investigation—some of them empty and others silicified in a matrix of limestone. Prof. E. J. Chapman (Professor of Geology and Mineralogy, Univ. Coll. Toronto) also kindly supplied me with several Russian Cystideans. To both of these gentlemen I here tender my thanks."—E. B.

eral aperture. According to these views, the mouth of a Cystidean does not stand in the centre of the radial system, as it does in all the existing Echinodermata. On this point Prof. Wyville Thomson has the following observations:—

"I can see no probability whatever in the opinion lately advocated by Mr. Billings, and which has received some vague support from the writings of De Koninck and others, that the 'pyramid' in the Cystideans is the mouth, and that the aperture whence the ambulacra radiate is simply an 'ambulacral orifice.' Such an idea appears to me to be contrary to every analogy in the class. There can be no doubt of the existence of distinct openings for the passage of the ambulacral nerves and vessels from the calyx of many of the palæozoic crinoids; but I think we must certainly assume that in this, as in all other known instances, these vessels had their origin in an annular vessel surrounding the mouth. In the whole class the œsophageal circular canal seems to be the origin and centre of the ambulacral system. It is the first part which makes its appearance in the embryo, and is so permanent and universal that one could scarcely imagine a radiating ambulacral vessel rising from any other source. The early origin of this important vascular centre, in this annular form and in this position, evidently depends upon, and is closely connected with, the origin of the nervous system in the œsophageal nerve-ring, constant in the whole Invertebrate series"*.

With all due deference, I cannot admit that we must assume that, in the Cystidea, the ambulacral tubes had their origin in "an annular vessel surrounding the mouth." It is true that such a vessel does surround the mouth of existing Echinodermata; but there is no essential or direct physiological connexion between the two organs. Their functions are exercised independently of each other. There is no organ issuing out of the alimentary canal that communicates with the annular vessel. This latter might be situated in any other part of the body, and still perform its functions, provided there were a connexion between it and the ambulacra. In this class the position of the various organs in relation to each other, and also to the general mass of the body, is subject to very great fluctuations. Thus the mouth and vent are separated in some of the groups, but united in others, while either or both may open out to the surface directly upward or downward, or at any lateral point. The ovaries may be either dorsal or ventral, internal or external, and associated with either the mouth, or the anus, or with neither. The ambulacral skeleton may be

* Edinburgh New Phil. Journal, vol. xiii. p. 112 (1861).

imbedded in and form a portion of the general covering of the body, or lie upon the surface, or be borne upon free-moving arms. In genera belonging to the same family these relations are constant or nearly so, but are found to be extremely variable when different orders or remotely allied families are compared.

While preparing my Decade No. 3, I investigated this subject, and satisfied myself that in at least a large proportion of the palæozoic Crinoids the mouth was disconnected altogether from the radial system. A great many species might be referred to in which we can see both the centre from which the ambulacra proceed, and the mouth, and at the same time see that they are not in the same place. A long train of reasoning is not necessary, only simple inspection. It will be quite sufficient to notice a few of these species to prove that the rule laid down by Prof. Wyville Thomson is not a general rule.

Fig. 1.

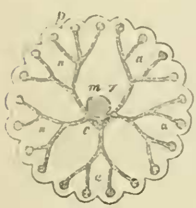

Fig. 2.

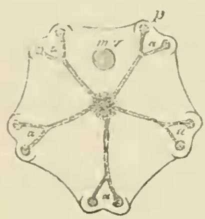

Fig. 3.

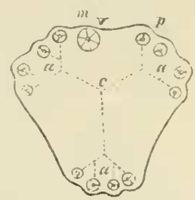

Fig. 1. This figure is a diagram of the interior of the vault of a Crinoid which appears to be *Batocrinus icosidactylus* (Cassiday), a fossil that occurs in the Carboniferous rocks of Kentucky. It was sent to me by Mr. S. S. Lyon, of Jeffersonville, Indiana, several years ago. The test is in a beautiful state of preservation, and perfectly empty, so that all of the markings on the inner surface can be distinctly seen. There are twenty-one arms arranged in five groups (*a*), and the same number of ambulacral openings (*p*), each just large enough to admit of the entrance of a slender pin. The mouth (*mv*) is nearly central; and close to it, on the posterior side, there is a small rudely pentagonal space (*c*) with no markings except several small tubercles. The grooves are scarcely at all impressed; and, indeed, I think they are never so in any Crinoid, except in those which have a thick test. In this specimen their course is clearly indicated by the remains of the thin partitions which either separated them or to which the vessels were attached. They do not run directly toward the mouth, as

they would do if that organ were the centre of the ambulacral system, but to the small space (*c*) behind it, where there appears to have been situated a vesicle or some other apparatus, to which all of them were united. Whatever may have been the structure of this central organ, from which the five main grooves radiate, it no doubt represented the annular vessel of the recent Echinodermata to which Prof. Thomson alludes.

Fig. 2 represents the structure of an *Amphoracrinus* from the Carboniferous rocks of Ireland (precise locality and species not determined). There are ten arms; the test is very thick; the ambulacral channels converge to the central point, but do not quite reach it; the mouth (*mv*) is about halfway between the centre and the margin. In this Crinoid it is perfectly impossible that the mouth can be the centre of the radial system, because the two anterior passages, between which it is situated, are for their whole length tunnelled, as it were, through the substance of the plates, and only penetrate downward into the interior at the central space.

Fig. 3 is a plan of the summit of the widely known and remarkable fossil *Caryocrinus ornatus* (Say). In this species there are only three, instead of five, groups of arms. In large individuals there are from twelve to twenty free arms (but always arranged in the three groups), with a small pore at the base of each. This pore is about the size of the ovarian pore of an *Echinus*, and can only be seen in well-preserved and clean specimens. The ambulacral grooves have not yet been observed, but their course is indicated by three low rounded ridges, which may be seen, in some specimens, radiating from a large heptagonal plate situated at *c*. The mouth (*mv*) is valvular, composed of from five to eight or ten plates, and is always situated near the margin between the two anterior groups of arms. With the exception of the ambulacral pores, there is positively no other aperture in the summit of *Caryocrinus*. If it be true that the mouth of an Echinoderm must be always situated in the radial centre, then *Caryocrinus* and also nearly all the palæozoic genera were destitute of that aperture.

Caryocrinus is a genus which seems to form a connecting link between the Crinoidea and the Cystoidea. By examining numerous well-polished sections, I find that the structure of the respiratory areas is the same (in general plan) as that of the genera *Glyptocystites*, *Pleurocystites*, and *Echinoencrinites*, as will be shown further on. The arms are also arranged in three groups, as in *Sphæronites* and *Hemicosmites*, while the mouth is valvular. On the other hand, the long cylindrical column and the arrangement of the arms around the margin, with the ambulacral pores at their bases, are Crinoidal characters.

In addition to the above, the following species may be referred to as examples of Crinoids with the mouth separate from the centre of the radial system :—

Amphoracrinus tessellatus (Phillips). Figured by J. Rofe, Esq., Geol. Mag. vol. ii. p. 8, fig. 3. The figure represents a cast of the interior of the vault, showing the five ambulacral grooves in relief. The mouth is situated in the angle between the two anterior grooves.

Strotocrinus perumbrosus (Hall, sp.). Figured by Meek and Worthen in the 'Geology of Illinois,' vol. ii. p. 188, f. 5. The specimen is 13 lines in diameter, the ambulacral centre 13 lines from the anterior margin, and the mouth 11 lines*.

Glyptocrinus armosus (M'Chesney, sp.). This extraordinary Crinoid is figured by M'Chesney in his 'New Pal. Foss.' pl. 7. f. 6, and also by Prof. Hall, in the 20th Reg. Rep. N. Y. pl. 10. f. 11. The specimens are between 2 and 3 inches in length. There are ten arms; the anterior side is much inflated; the proboscis appears to be large at its base and excentric in its position, but, instead of standing erect, it bends down to the surface of the vault, and lies upon it, crossing over to the posterior margin. Judging from the figures, the centre of the

* In April last I received from Messrs. Meek and Worthen a paper entitled "Notes on some points in the Structure and Habits of the Palæozoic Crinoidea." Of all the papers relating to this subject yet published on this continent, this one (at least, so it appears to me) is the most interesting and important. It is written with a clearness and particularity rarely to be seen in palæontological memoirs. In some respects it confirms the opinions advocated in these notes, but bears directly against my views on the question here under discussion, *i. e.* "the position of the mouth with relation to the radial centre." As I wish to give the remarkable observations of the authors full consideration, I shall not discuss them now, but delay until the September No. of this Journal. [Meek and Worthen's paper is given in Silliman's Journal, July 1869, p. 23.] I shall only state here that I believe that the grooves on the ventral disk of *Cyathocrinus*, and also the internal "*convoluted plate*" of the palæozoic Crinoids, with the tubes radiating therefrom, belong to the respiratory and perhaps, in part, to the circulatory systems—not to the digestive system. as is supposed by the authors. The convoluted plate, with its thickened border, seems to foreshadow the "œsophageal circular canal," with a pendent madreporic apparatus as in the Holothuridea. To me the final determination of this question is of much importance; for if Meek and Worthen are right, then I must be wrong so far as regards nearly all that I have published with reference to the functions of the apertures of the palæozoic Echinodermata. It is fortunate that the solution of this curious problem is now undertaken by men who have access to the magnificent cabinets of the geologists of the western States, and also by men who habitually discuss scientific subjects with the sole object in view of arriving at the truth.

base of this organ must be distant from the radial centre at least one-fourth of the whole width of the vault. *G. siphonatus* (Hall), figured on the same plate, shows that the anterior grooves curve round to the posterior side of the proboscis, as they do in *B. icosidactylus* above cited.

I should also state here that, two or three years ago, Mr. Meek, to whom I had written for information on this subject, wrote me that in all cases where he had observed the grooves on the interior of the vault, they radiated, not from the mouth, but from a point "in front of it." (This would not be in front of, but behind, the mouth, according to the terminology used in these notes. I think that the side in which the mouth is situated should be called "anterior" or "oral," even although both the mouth and anus should be included in it.)

In all the species above cited, the figures (with the exception of that of *C. ornatus*) exhibit the relative position of the mouth and radial centre as it has been actually seen in casts of the interior of the vault. But, besides these, numerous examples may be found in the works of Miller, Austin, De Koninck, Phillips, Meek, Worthen, Shumard, Hall, Lyon, Cassiday, and others, of Crinoids whose external characters show that, in them, the mouth cannot be in the central point from which the grooves radiate.

With respect to Prof. Thomson's theory, I freely admit that, if it is true that in all the Echinodermata, fossil and recent, the mouth is the radial centre, then that aperture must be the one which I call the ambulacral orifice in the Cystidea. The views, however, advocated by me in my Decade No. 3 appear to be gradually gaining ground. As these fossils are rare, few have occasion to study them ; and consequently the subject has not been much discussed since 1858, the date of the publication of that work. The following are the only authors, so far as I have ascertained, who have given their opinions on this vexed question during the last eleven years :—

Prof. Wyville Thomson, *op. cit.* p. 111 (1861), agrees with me that the lateral aperture is not an ovarian orifice, but, as we have seen, is strongly opposed to the view that it is the mouth. He calls it the anus.

Prof. Dana (Man. Geol. p. 162, 1863) recognizes it as the homologue of the simple aperture (oral and anal) in the summit of those Crinoids which have but one. This is exactly my view. [J. W. Salter agrees with Prof. Thomson that it is the anus, not the ovarian aperture (Mem. Geol. Sur. G. B. vol. iii. p. 286, 1866.) Prof. S. Lovén, of Stockholm, has described, in the 'Proceedings of the Royal Swedish Academy,' 1867, the remarkable sea-urchin, *Leskia mirabilis* (Gray), which has the mouth constructed on the same plan as that of the Cystidea—that is to say, with five triangular valve-like plates, which are immediately attached to the interambulacral plates, without the intervention of a buccal membrane. After comparing this structure with the valvular orifice of *Sphæronites pomum* (Gyll.), he says:—"that the 'pyramid,' which in *Leskia* is the armature and covering of the mouth, is the same thing in the Cystidea is now quite certain; in the last-named group it was, doubtless, also the vent. The mouth does not lie where J. Müller and Volborth sought for it, viz. in the centre of the ambulacral furrows; and the organ interpreted as the vent by Volborth and Von Buch, is more correctly regarded as an external sexual organ." (Geol. Mag. vol. v. p. 181, Dr. Lütken's transl.)]

2. *On the Pectinated Rhombs and Calycine Pores of the* Cystidea.

None of the organs of the Echinodermata have been the subject of so much speculation as the calycine pores and the so-called "pectinated rhombs" of the Cystidea. Their relations and function long remained in doubt; but there seems to be now sufficient data to show that they are respiratory organs, and also that they are the homologues of the tubular apparatus which underlies the ambulacra of the Blastoidea. J. Müller suggested a comparison between these peculiar organs and the respiratory pores of the Asteridæ (Ueber den Bau der Echinodermen, p. 63, 1854). Prof. Huxley has placed them in the same relation (Medical Times, Dec. 1856). Eichwald calls them respiratory pores (Lethæa Rossica, vol. i. p. 614: 1860). Prof. Dana says "they are probably connected with an aquiferous system and respiration" (Man. Geol. p.162 : 1863). Mr. Rofe, after showing that their structure is the same as that of the striated surfaces between the rays of *Codaster*, says, "From the construction of these striations on the face of *Codaster*, and on the 'pectinated rhombs' of the Cystidea, may we without assumption suggest the possibility of their being respiratory sacs, lined with cilia, and constructed of a porous test, through which air from the water could pass by diffusion" (Geol. Mag. vol. ii. 251 : 1865). As for myself, when I prepared my Decade on the Cystidea, I gave this subject a great deal of consideration, and studied a large number of specimens, but could arrive at no conclusion satisfactory to myself. I am now convinced that the view of the above-named distinguished authors is the correct one. These are respiratory organs. In all the species in which they occur they seem to be constructed on the same general plan, *i. e.*

the interposition of an exceedingly thin partition between the circumambient water and the fluid within the general cavity of the body. They are usually of a rhomboidal shape, each rhomb being divided into two triangles by the suture (*c c*, figs. 4, 5) between two of the plates. In several of the genera the two halves of the hydrospires are reniform, ovate, or lunate, and either internal or external.

Fig. 4.

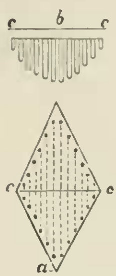

Fig. 5.

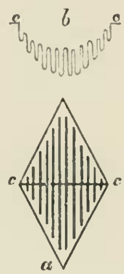

Fig. 6.

Fig. 7.

Fig. 4. Hydrospire of *Caryocrinus ornatus*: *a*, surface view, the dots around the margin are the spiracles, the small dotted lines represent the course of the flat internal canals; *c c*, suture between the two plates; *b*, transverse section. Fig. 5. Hydrospire of *Pleurocystites*: *a*, surface view; *c c*, suture; *b*, transverse section. Fig. 6. The same, with the points *c c* drawn together. Fig. 7. Internal gill of a spider.

In order to avoid the use of double terms, I propose to call them "*hydrospires*," and their apertures "*pores*," "*fissures*," or "*spiracles*," according to their form.

In *Caryocrinus ornatus* the hydrospires (fig. 4) are of a rhomboidal form, and have each of the four sides bordered by a single row of small tubercles. Some of these tubercles have a single pore in the summit, while others are perforated with a variable number—from two to twenty, or perhaps more, thus becoming vesicular or spongy. It is only the apex of the tubercle, however, that has this structure; for when this is worn off, there is only a single pore to be seen. The pores penetrate through the plates, but do not communicate directly with the general cavity of the body. Internally each hydrospire consists of a number of flat tubes arranged parallel to each other and lying side by side, in the direction of the dotted lines in fig. 4 *a*. Each tube receives two of the pores seen on the exterior—one pore at each end. These tubes are composed of a very thin shelly membrane, which, although possessed of sufficient rigidity to maintain its form, was, no doubt, of such a minutely porous texture as to admit of the transfusion of fluids in both directions—outward and inward.

In a large hydrospire there are about twenty of those tubes; their greatest breadth is at their mid-length, where they are crossed by the suture (*c c*); and as they become narrower accordingly as their length decreases, the one in the middle projects the deepest into the perivisceral cavity. In consequence of this arrangement, when a section is made across the hydrospire at the suture, *c c*, fig. 4 *a*, the form *b* is obtained, where *c c* is the surface of the shell, while the comb-like structure below represents the tubes.

Specimens of *C. ornatus* almost entirely empty are often found; and in some of these the internal form of the hydrospires is sometimes preserved. Those that I have seen have the form of small rhomboidal pyramids, with four slightly convex sloping faces, and composed of a number of vertical parallel plates (the casts of the interior of the tubes), the substance of the tube itself not being preserved. I have, however, several polished transverse sections in which I think the thin walls can be seen.

The structure of the hydrospires is such that there can scarcely be any doubt that they are respiratory organs. The sea-water entered through the pores, and aërated the chylaqueous fluid contained in the perivisceral cavity by transfusion through the exceedingly thin membranous shell that composed the walls of the tubes. The number of pores varies with the size of the individual. In large specimens there are from 800 to 1000.

It has been stated by some authors that the pores were passages for the protrusion of internal organs connected with the vitality of the animal. The fact, however, that the pores do not penetrate into the general cavity of the body disproves this theory; and, moreover, through many of the tubercles (those with a vesicular and spongy summit) such protrusion would be utterly impossible.

In *Caryocrinus ornatus* there are thirty hydrospires, arranged as follows:—

1. Ten at the base—half of each on a basal plate and the other half on one of the subradials, their longer diagonal vertical.

2. A zone of six around the fossil at the mid-height, their longer diagonals horizontal. These seem to be imperfectly developed; for, on the inside, the tubes occupy only a small space in the centre.

3. A third band, of fourteen—two of them with their longer diagonals vertical, and the others arranged in six pairs, the diagonals of each pair inclining toward each other upward at an angle of about 30°. There are only three interradii in

Caryocrinus; the mouth is placed in one of them, and the two hydrospires with vertical diagonals in the other two.

In *Pleurocystites* the hydrospires are also of a rhomboidal form; but, instead of having the tubular structure of *Caryocrinus*, they consist of a number of parallel inward folds of an exceedingly thin part of the shell. These folds, no doubt, represent the tubes of *Caryocrinus*. If we grind down a hydrospire of this latter, so as to remove all the shell, and expose the edges of the tubes, it then presents precisely the same form as fig. 5 *a* (*i. e.* the form of a rhomb longitudinally striated at right angles to the suture, and with no pores). The transverse section in *Pleurocystites* only differs from that in *Caryocrinus* in having no shell between the points *c c*. In the hydrospire of *Pleurocystites robustus*, of the Trenton Limestone, we have the commencement of the formation of an internal gill with a single spiracle. The surface is not flat, as it is in many species, but concave, as shown in the section; and it is evident that if the concavity were carried further, and at the same time the points *c c* made to approach each other, the effect would be to produce an elongated sac, deeply folded on one side, and with a fissure extending the whole length on the other side. The transverse section of such a sac would be fig. 6, the same as in *Pentremites*. Again, if we contracted the four sides, gradually curving them outward at the same time, but not diminishing the superficial extent of the walls of the folds, although altering the form to correspond with the decreasing aperture, the result would be a deeply folded flask-shaped sac, with a small round orifice like fig. 7, which is the internal gill of a spider.

In *Palæocystites tenuiradiatus*, a species very characteristic of the Chazy Limestone, the whole surface (in the condition in which the fossil is usually found) is covered with deeply striated rhombs, the fissures being deepest where they cross the suture, and growing gradually shallower as they approach the centre of the plates, where they die out altogether. Detached plates occur in vast abundance, but no perfect specimens have ever been found. I discovered, however, several fragments of the body sufficient to give the general form and to show that, when the surface is perfect, all these fissures are completely covered over by a very thin shell, and that when they cross the suture, there is a small pore in the bottom of each which penetrates to the interior. The rhombs of this species are thus external hydrospires. The fissures seen in the ordinary weathered specimens are the remains of flat tubes like those of *Caryocrinus*, situated on the outer instead of the inner surface of the test. The chylaqueous fluid passed outward through the pores and filled the tubes, to be aërated through the thin external covering by the surrounding water. In *Caryocrinus* the water passed inward, through the pores, into the tubes, and aërated the fluid within the general cavity of the body.

The discovery that the fissures and pores of the Cystidea do not communicate directly with the general cavity of the body is entirely due to Mr. Rofe. After reading his highly important paper, I re-examined a great number of specimens, and found sufficient to confirm his observations.

3. *On the Genus* CODASTER.

Every author who has described a species of this genus has remarked the peculiar striated areas in the interradial spaces. Prof. M'Coy, the founder of the genus, pointed out their resemblance to the hydrospires of the Cystidea; but it was Mr. Rofe who first showed that they were also identical in structure therewith. On comparing one of these with that of the Cystidean *Pleurocystites* (fig. 5), we at once perceive that they are the same in external form, while Mr. Rofe's figures show that the section at *d d* (fig. 8) has the structure of fig. 9, which only differs from fig. 5 *b* in being straight above instead of concave, and in being divided into two parts. This division is the result of the position of the arm, which cuts the hydrospire in two in a direction parallel to the fissures. By drawing the points *d a* and *a d* together, we get figure 10, which is, in general plan, a section across one of the ambulacra of a Pentremite. On examining nearly all the published figures of species of this genus, I find that there is a series of forms which exhibit a gradual passage, from those with the hydrospires almost entirely exposed (as in fig. 8), through others, in

Fig. 8.

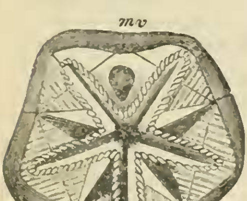

Fig. 9.

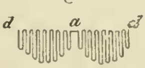

Fig. 10.

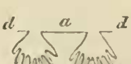

Fig. 11.

Fig. 8. Summit of *C. acutus*, M'Coy: *m v*, mouth and vent; *d d*, suture across the posterior hydrospire. Fig. 9. Section across the hydrospire from *d* to *d*; at *a* is the place of the arm. Fig. 10. The section contracted as in fig. 6. Fig. 11. Summit of *Pentremites caryophyllatus*, De Koninck.

which they are crowded more and more under the arms, until at length they become altogether internal.

In *C. acutus* (fig. 8) only a small portion of the hydrospire is concealed under the arm. In *C. canadensis*, a new species lately discovered in the shales of the Hamilton group in Canada West, each of the four interradial spaces in which the hydrospires are placed is excavated in such a manner as to form *a small triangular pyramid*, with two of its faces sloping down toward the sides of the two adjacent arms. On these two slopes are placed the hydrospires, which appear to have one fissure entirely under and another partly under the arm, five others being fully exposed. S. S. Lyon has described a species under the name of *C. alternatus*, in the 'Geology of Kentucky,' vol. iii. p. 494, from the Devonian rocks of that State, which closely resembles *C. canadensis*, but is still distinct therefrom. Speaking of the structure of the summit, he says:—"The depressed triangular intervening spaces are filled with seven or more thin pieces, lying parallel to the pseudambulacral fields, articulating with the summit of the second radial, and the prominent ridge lying between the pseudambulacra. These pieces were evidently capable of being compressed or depressed: the '*point*' at the lateral junction of the second radials is in some specimens folded over toward the mouth, so as to entirely obscure these triangular spaces by covering them." This important observation proves that even in the same species the hydrospires may be either partly or wholly concealed under the arm. The "*point*" to which Mr. Lyon alludes is seen above, in fig. 11, just below the letter *h*; it is the same as the "*small triangular pyramid*" in *C. canadensis*. It is evident that (supposing the shell to be flexible), if these points were to be drawn inward, the movement would gradually cause what remains exposed of the hydrospire to be covered, until at length it would be entirely concealed under the arm. The five points would then be situated in the angles between the five ambulacra, as they are in the genus *Pentremites* (fig. 15). The concealment of the hydrospires may also be the result of the widening of the arm. This is well shown in *P. caryophyllatus*, De Koninck (*P. Orbignyanus*, according to Roemer), *P. Schultzii*, DeVern., and several other species. In these the apices of the pyramids remain near the margin; but the hydrospires are nearly covered by the wide arms. This is shown in fig. 11, where the ends of the fissures of the hydrospires are seen along the sides of the angular ridges which extend from the apices of the pyramids to the angles between the arms. I do not think that such species can be referred to *Pentremites*; and if I had specimens before me instead of figures only, I should most probably institute a new genus for their reception.

Our specimens of *C. canadensis* are well preserved, and show the characters of the arms perfectly. After many careful examinations under the microscope, I can state positively that in this species the so-called "pseudambulacral fields" have no pores. The markings that have hitherto been mistaken for ambulacral pores in *Codaster* are not pores, but the small pits or sockets which received the bases of the pinnulæ. The rays therefore in this genus are not "pseudambulacral fields," in the sense in which that term is used in descriptions of species of *Pentremites*, but simply recumbent arms, identical in structure with those of the Cystidean genera *Glyptocystites*, *Callocystites*, *Apiocystites*, and others. They lie upon the surface of the plates which constitute the shell of the animals—not imbedded in them, as in *Pentremites*. The large lateral aperture is both mouth and vent, and the central opening heretofore called the mouth is the ambulacral or, more properly, the ovarian orifice. As therefore *Codaster* has the arms of *Apiocystites*, the hydrospires of *Pleurocystites*, and the confluent mouth and vent common to all Cystideans, I propose to remove it from the Blastoidea and place it in the order Cystidea.

4. *On the Genus* Pentremites.

In *Pentremites* the hydrospire is an elongated internal sac, one side of which is attached to the inside of the shell, while the side opposite, or toward the central axis of the visceral cavity, is more or less deeply folded longitudinally. There are two of these to each ambulacrum, attached along the two lines of pores. There appears to be a fissure extending nearly the whole length in the direction of the dotted line *f* (fig. 12). One edge of this fissure is attached to the lancet plate, along one side of the line of pores, the other to the shell, on the other side of the row. The pores all enter the hydrospire through this fissure. There are ten hydrospires, connected together in pairs, each pair communicating with the exterior through a single spiracle. The arrangement of the folds varies according to the species. In *P. Godoni* there are five folds, the outer sides of which are close up to the inner side of the lancet plate (fig. 13). In a specimen of *P. obesus*, Lyon, nearly two inches in diameter at the mid-height, the hydrospires extend inward about three lines, the main body being about one line from the lancet plate. There are five folds, each two lines deep; and thus, if the thin shelly membrane which constitutes the wall of the hydrospire were spread out, it would have a width of twenty-two lines; and the ten together would form a riband about eighteen inches in length and nearly two inches wide. The object of the folding is, of course, to confine this large amount of surface to a small space—an arrangement which at once proves the function to be respiratory. Of those figured by Mr. Rofe, *P. ellipticus*, Sowerby, appears to have only one fold; *P. inflatus*, idem, shows eight folds in one and eleven in the other hydrospire of the same ambulacrum. Another specimen, figured by Mr. Rofe under the name of *P. florealis*, Say, has five folds situated at a distance from the inner surface of the lancet plate, as in *P. obesus*. From the form of the organ, I think that Mr. Rofe's specimen cannot be the species called *P. florealis* by Say.

If it be granted that these organs are respiratory in their function, then their five apertures should be called *spiracles*,

Fig. 12.

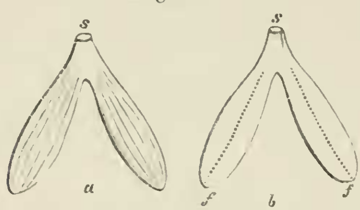

Fig. 13.

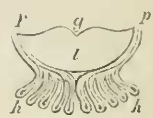

Fig. 14.

Fig. 15.

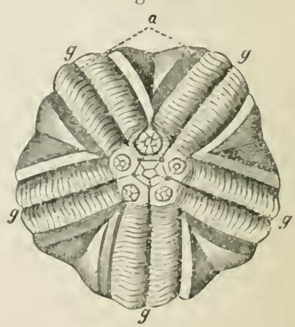

Fig. 12. Diagrams of one pair of the hydrospires of a Pentremite: *a*, the inner side; *b*, the outer, or side attached to the shell; *f*, the fissures. Fig. 13. Section across an ambulacrum of a specimen of *P. Godoni*, enlarged 3 diameters: *l*, lancet plate: *g*, ambulacral groove; *p p*, pores leading into the hydrospires; *h h*, the two hydrospires, in transverse section. Fig. 14. Ideal figure of a transverse section through an entire specimen, showing the ten hydrospires: *l*, one of the five lancet plates; *p p*, pores; *r r*, the two branches of one of the radial plates. Fig. 15. Summit of *P. conoideus*: *a*, anterior side; *g*, ambulacral grooves (copied from Dr. Shumard, but with the ovarian pores added).

not "ovarian orifices." The large anterior aperture would thus be the *oro-anal spiracle*. Applying this system of terminology to other groups, the so-called ovarian orifice of the Cystidea, the homologous aperture of *Nucleocrinus*, *Codaster*, *Granatocrinus*, and of the palæozoic Crinoidea generally (but not of the recent forms) should be styled the *oro-anal orifice*.

I think that the side of an Echinoderm in which the mouth is situated should be called "anterior," even although the anus and the mouth be confluent in one orifice. Most starfishes have but one aperture for mouth and vent, and yet it is called the mouth by naturalists generally. Why not call the underside of a starfish "the anal or posterior side," and the central aperture the "anus?"

Dr. B. F. Shumard has shown (Trans. Acad. Nat. Sci. St. Louis, vol. i. p. 243, pl. 9. fig. 4) that in perfect specimens of *P. conoideus*, Hall, the six summit-apertures are closed by several small plates. In a specimen of the same species, sent me by Mr. Lyon, in which those plates are partly preserved, I find that there is a small pore in each of the five angles of the central aperture. The five ambulacral grooves enter the interior through these pores. I have copied his figure, but modified it by adding the pores, fig. 15. He also found that the summit of *P. sulcatus*, Roemer, was covered with an integument of small plates arranged in the form of a pyramid. From these facts he infers that in all the Pentremites the summit-apertures will be found, in perfect specimens, to be closed in a similar manner.

Dr. C. A. White, at present State Geologist of Iowa, in a paper on the same subject (Bost. Journ. N. H. vol. viii. pp. 481–488), describes *P. Norwoodii*, Owen and Shumard, and *P. stelliformis*, id., as having a similar structure; but he goes further: he considers the central orifice "*not to be the mouth*;" and I believe that he is the first naturalist who ever published such an opinion. His idea of its function is thus expressed:—"It seems more probable that, as the ova were germinated within the body, they found their exit through the central aperture, and were conveyed along the small central grooves of the pseudambulacral fields before mentioned, beneath the plated integument, to the bases of the tentacula, where they were developed and discharged as in the true Crinoids." I perfectly agree with Dr. White in this view. The central aperture is not the mouth; in fact, it is not a natural orifice, but a breach in the summit caused by the destruction of a portion of the vault. The true natural orifices of this part are those that I have discovered in *P. conoideus*, as above mentioned. They are the homologues of the *ovarian* *pores* at the bases of the arms of *Caryocrinus*, and in part, as I shall show in another part of these notes, of the ambulacral orifices of the true Crinoids.

With regard to the structure of the calyx of *Pentremites*, it is generally supposed that there are only three series of plates —the basal, radial, and interradial. Mr. Lyon has advanced the opinion that there are three small plates below those now called the basals (Geol. Ky. vol. iii. p. 468, pl. 2. fig. 1 *c*). I have examined a number of specimens with reference to this point, and I think he is right. There are three small pentagonal basals, the two upper sides of each of which are excavated to receive the subradials, *i.e.* those at present designated "the basals." They are in general anchylosed to the subradials; but in one of Mr. Lyon's specimens that I have seen they are distinctly separate.

[To be continued.]

XXVII.—*Note on an undescribed Fossil Fish from the Newsham Coal-shale near Newcastle-upon-Tyne.* By Albany Hancock, F.L.S., *and* Thomas Atthey.

For several years past we have been much puzzled with a large ichthyic tooth that is not by any means uncommon at Newsham. We could not make out to what fish to assign it. Indeed there is but one, of sufficient size, found in the locality, of which the teeth are not known, that was at all likely; and the remains of this were supposed to belong to *Rhizodus*; and as the teeth in question are perfectly devoid of cutting-edges, they could not belong to it. We had doubts, however, as to these remains really being those of that obscure fossil, and thought that probably they would be found some day or other associated with our unknown tooth—that it belonged, in fact, to these supposed *Rhizodus*-bones. And such is apparently the case.

A jaw has just been obtained at Newsham with one of these large enigmatical teeth attached, and the surface-ornament of the bone is of the same character as that of the remains alluded to. This jaw, which is a left mandible, is quite perfect in front; but the proximal extremity is broken away. The part that remains is upwards of seven inches long, and an inch and five-eighths wide; the margins are nearly parallel; the alveolar border is pretty straight, but rises up a little in front, which is rounded. About an inch behind the anterior extremity, a large stout laniary tooth is placed on this elevated part; it is slightly recurved, but the apex is gone. What remains mea-